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PRELIMINARY AIRWORTHINESS EVALUATION OF THE UH-60 HELICOPTER WITH T700-GE-701A ENGINES INSTALLED

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FINAL REPORT

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USAAEFA

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The US Army Aviation Engineering Flight Activity conducted a limited Preliminary Airworthiness Evaluation of the T700-GE-701A engine installation in the UH-60A Helicopter on 24 and 25 June 1983. The evaluation was conducted at the Sikorsky Flight Test facility at West Palm Beach, Florida (field elevation 28 ft) on aircraft S/N 77-22714. The evaluation consisted of three flights for a total of 4.8 productive flight hours. The significant increase in power available for single engine contingencies (262 shaft horsepower (22%) at 4000 ft pressure

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altitude, 95°F) is an enhancing characteristic. The excellent torque matching engine stability and rotor speed control with one engine in electrical control unit lockout and the power lever set for level flight at 80 knots indicated airspeed is also an enhancing characteristic for the T700-GE-701A engine ~~as well as the~~ and T700-GE-700 engine. The UH-60A acceleration, deceleration, and normal maneuvering response characteristics are essentially the same with either the T700-GE-700 engine or T700-GE-701A engine installed. Two shortcomings were identified: (1) ~~the~~ slow engine acceleration during collective pulls from approximately zero torque to 50% or greater torque; and (2) ~~the~~ rotor droop to less than 95% rotor speed during collective pulls from zero torque and during aggressive maneuvers such as a quick stop from the maximum airspeed in level flight. During the evaluation a popping sound was noted during collective pulls to approximately 80% and greater torque settings. This popping sound was subsequently identified as "oil canning" on the fuselage skin between the pilot's station and gunner/crew chief's window. (approximate fuselage station 262).

DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120

REPLY TO
ATTENTION OF

DRSAV-E

SUBJECT: Directorate for Engineering Position on the Final Report of USAAEFA Project No. 83-17, Preliminary Airworthiness Evaluation of the UH-60A Helicopter with T700-GE-701A Engines Installed

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. The subject evaluation was conducted to determine the compatibility of the T700-GE-701A engines in the production UH-60A in lieu of the T700-GE-700 engines. The significantly increased performance of the T700-GE-701A engine will enhance the capabilities of the UH-60A at the increased gross weights with Extended Stores Support System (ESSS). It also will increase safety at the lighter gross weights, particularly with the increased shaft horsepower (SHP) using contingency power under single engine conditions.

2. This Directorate agrees with the report conclusions and recommendations. Based on the flight test results, the T700-GE-701A engine is compatible with the UH-60A.

FOR THE COMMANDER:

RONALD E. GORMONT
Acting Director of Engineering

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INTRODUCTION

BACKGROUND

1. The US Army Aviation Research and Development Command tasked the US Army Aviation Engineering Flight Activity to plan, conduct, and report on a Preliminary Airworthiness Evaluation (PAE) of the Sikorsky UH-60A Helicopter with General Electric T700-GE-701A engines installed (ref 1, app A).

TEST OBJECTIVE

2. The objective of this PAE was to obtain flight test data for qualification of the T700-GE-701A installation in the UH-60A helicopter.

DESCRIPTION

3. The test aircraft was modified to accept the prototype External Stores Support System and the T700-GE-701A engines. The aircraft description with the T700-GE-701A is defined in the UH-60A preliminary Prime Item Development specification (ref 2, app A). The T700-GE-701A engine is defined in the preliminary model specification (ref 3). The T700-GE-701A changes include a 10 minute power rating and a 2.5 minute contingency power rating (CPR). The 2.5 minute rating provides an increase of 262 shaft horsepower (SHP) (22%) at 4000 ft pressure altitude (Hp), 95°F. A more detailed description is contained in appendix B.

TEST SCOPE

4. The T700-GE-701A PAE was conducted at the Sikorsky West Palm Beach Test Facility, on 24 and 25 June 1983, for a total of 4.8 productive flight hours. All test support, including maintenance, servicing, chase, standby crash rescue helicopter and crew, office space, data reduction and final data plots were provided by Sikorsky. Flight restrictions and operating limitations observed during the evaluation are contained in the operator's manual (ref 4, app A) and the airworthiness release (ref 5). Testing was conducted in accordance with the test plan (ref 6) at the conditions shown in table 1.

TEST METHODOLOGY

5. The flight test data were obtained from test instrumentation and recorded on magnetic tape installed in the aircraft. A

Table 1. Test Conditions[1]

Test	Pressure Altitude (ft)	Calibrated Airspeed (kt)	Remarks
Engine Acceleration[2]	3000	80	2 rates, several power settings to IRP[3]
Engine Deceleration[2]	3000	80	2 rates, several power settings to autorotation
Pull-Up and Push-Over	3000	80 to V_H[4]	2 rates of application
Static Droop	Surface[5] to 1000	80 to V_{NE}[6] to 0	Trim rotor speed on ground at flat pitch, fly envelope without retrimming
Quick Stop	1000	V_H to 0	2 rates
Longitudinal Flare Deceleration	1000	V_H to 0	2 rates, fixed collective (altitude change acceptable)
Jump Takeoff	Surface[5]	0	2 rates
Engine Stability	3000	80	Collective and pedal pulses
ECU Lockout	3000	80	Torque matching engine stability and rotor speed control with one engine in ECU lockout
Contingency Power	1000	80	Power limits

NOTES:

[1]Engine Start Gross Weight = 17,500 lb, longitudinal center of gravity = 354 in., (mid), rotor speed = 258 RPM
[2]Single engine and dual engines
[3]IRP = intermediate rated power
[4]V_H = the maximum airspeed in level flight at intermediate rated power
[5]Field elevation = 28 feet
[6]V_{NE} = never exceed airspeed

detailed listing of the test instrumentation is contained in appendix C. Flight test techniques described in references 7 and 8, appendix A were used. A discussion of the test techniques and data analysis methods is contained in appendix D. A Cooper-Harper Handling Qualities Rating Scale (HQRS) (fig. 1, app D) was used to augment pilot comments relative to handling qualities. Time histories of selected parameters were computer printed.

RESULTS AND DISCUSSION

GENERAL

6. A limited PAE of the T700-GE-701A engine installation on the UH-60A was conducted at 3000 feet pressure altitude. The contingency power capability was evaluated at 1000 feet H_P. The CPR of the T700-GE-701A engine is an enhancing capability which provides an added margin of safety for emergency single engine operations. The excellent torque matching engine stability and rotor speed control with one engine in electrical control unit (ECU) lockout and the power lever set for level flight at 80 knots indicated airspeed (KIAS) is also an enhancing characteristic. The UH-60A acceleration, deceleration, and normal maneuvering response characteristics are essentially the same with either the T700-GE-700 engine or T700-GE-701A engine installed. Two shortcomings were identified: (1) the slow engine acceleration during collective pulls from approximately zero torque to 50% torque or greater power settings, and (2) the rotor droop to less than 95% rotor speed (N_R) during collective pulls from zero torque and during aggressive maneuvers such as a quick stop from the maximum airspeed in level flight (V_H). A popping sound determined to be "oil canning" was heard at approximately fuselage station 262 when collective was increased to approximately 80% torque or greater.

ENGINE ACCELERATION

7. Engine acceleration time histories are presented in figures 1 through 6, appendix E. T700-GE-701A acceleration rates appeared to be unchanged from T700-GE-700 accleration rates. Comparative -700 acceleration rates are presented in figures 5 and 6, appendix E. Torque matching during dual engine collective pulls was generally excellent (within approximately 1%). One to two second collective pulls from zeró torque to 50% torque or greater resulted in a transient rotor droop below 90% N_R (91% N_R is minimum transient). Collective pulls from 20% torque or greater to intermediate rated power (IRP) did not result in rotor droop below 95%. The transient rotor droop, below 95%, caused the audio and visual warning systems to activate. These warning signals and the accompanying aircraft yaw oscillations caused the pilot to divert his attention inside the cockpit resulting in loss of outside cues of vertical and lateral obstacle separation. The slow engine acceleration and resulting rotor speed droop degrades the aircraft's capabilities to perform aggressive maneuvers such as high rate descents to cover, masking/remasking, and quick stop. The slow engine acceleration from near zero torque to 50% or greater power settings is a shortcoming.

The transient rotor droop to less than 95% N_R during collective pulls from approximately zero torque to 50% torque or greater, and during aggressive maneuvers such as a quick stop from V_H and the resulting aircraft response is a shortcoming.

ENGINE DECELERATION

8. The T700-GE-701A engine deceleration characteristics were evaluated at the conditions shown in table 1. Representative time histories are presented in figure 7 and 8, appendix E for dual and single engine collective reductions. The most aggressive collective reductions (from IRP to full down collective in approximately 2 seconds) resulted in approximately a 4% power turbine speed (N_P) overshoot (107% is allowed for up to 12 seconds). However, the recovery (approximately a 30% collective pull from zero torque) resulted in a signficant N_R droop to about 96% for the dual engine recovery, and a N_R droop to about 93% (minimum transient N_R droop is 91%) for the single engine recovery for a 37% collective pull. The T700-GE-701A engine deceleration characteristics are satisfactory.

PULL-UP AND PUSH OVER

9. The engine/airframe response characteristics during pull-ups and push-overs were evaluated at the conditions shown in table 1. A time history is presented in figure 9, appendix E. Rotor speed and power turbine speed varied $\pm 2\%$ during the maneuver. The T700-GE-701A engine/airframe response during pull-up and push over maneuvers is satisfactory.

STATIC DROOP CHARACTERISTICS

10. The static droop characteristics of the T700-GE-701A engine were evaluated by setting N_R to 100% then conducting a normal takeoff and IRP climb to 1000 feet, accelerating to V_H, diving to the limit airspeed in forward flight (V_{NE}) and returning to a hover. There was no static droop. Within the limited scope of this test, the static droop characteristics of the UH-60A with T700-GE-701A engines installed are excellent.

QUICK STOP

11. The T700-GE-701A engine/airframe characteristics during quick stop maneuvers were evaluated in a level deceleration from V_H to a hover. The maneuver was performed by starting at V_H, then

reducing the collective to essentially full down and adjusting the cyclic to maintain constant altitude above the ground. A representative time history is presented in figure 10, appendix E. The rotor speed increased to 107% (within handbook limits of 110%) during the deceleration. The power turbine speed followed the rotor speed to approximately 103%, then split down to 100% until the collective was increased at the end of the flare. The power turbine speed then increased to 104% joining the decreasing rotor speed. The recovery at completion of the quick stop resulted in the N_R drooping to approximately 92%. During the recovery, approximately 30 feet of altitude was lost while the engines were accelerating to hover power. The aircraft yawed to the left as initial collective pitch was applied then to the right as engines accelerated to hover power. The low rotor audio and visual warning systems activated. This caused the pilots attention to be diverted inside the cockpit and required extensive pilot compensation to complete the maneuver (HQRS 6). The slow engine acceleration characteristics and resulting rotor droop are shortcomings which degrade the mission maneuvering capability of the aircraft.

LONGITUDINAL FLARE DECELERATION

12. Longitudinal flare deceleration characteristics were evaluated at the conditions shown in table 1. The maneuver could not be completed with the collective fixed due to the increase in torque and turbine gas temperature (TGT) as the airspeed was reduced. A representative time history is presented in figure 11, appendix E. The T700-GE-701A/UH-60A engine response characteristics during collective fixed longitudinal flares are satisfactory.

JUMP TAKEOFF

13. T700-GE-701A/UH-60A jump takeoff characteristics were evaluated at two different rates of collective pulls to IRP. Representative time histories are presented in figures 12 and 13, appendix E. Although the rotor drooped to less than 95% causing the audio and visual warning to activate, the aircraft was climbing and clearing all obstacles, thus the pilot did not sense and in fact was not approaching a hazardous situation. The jump takeoff characteristics of the T700-GE-701A engines installed in the UH-60A are satisfactory.

ENGINE STABILITY

14. The T700-GE-701A/UH-60A engine/airframe stability characteristics were evaluated using separately, both pedal and collective

pulses. Representative time histories are presented in figures 14 through 16, appendix E. There was no indication of engine/airframe instability during either the collective or pedal pulses, and although not indicated by the time histories, the oscillations were highly damped when the control input pulsing was terminated. The T700-GE-701A/UH-60A engine/airframe stability response characteristics are satisfactory.

ENGINE ELECTRICAL CONTROL UNIT (ECU) LOCKOUT

15. The T700-GE-701A engine characteristics while operating in ECU lockout were evaluated by setting power for level flight at 80 KIAS, then placing one power lever in ECU lockout, and manually resetting that engine torque to match the governed engine. ECU lockout was easily attained and power lever adjustment to match torques was quickly and easily accomplished. A representative time history is presented in figure 17, appendix E. With the engine operating in manual control set as described above, the aircraft was accelerated to V_H, decelerated to a hover, landed, and the collective reduced to full down. The torque matching provided by the load demand spindle was excellent when the power lever was set for level flight at 80 KIAS. The excellent torque matching engine stability and rotor speed control with one engine in ECU lockout and the power lever set for level flight at 80 KIAS enhances mission accomplishment when operating in a degraded mode. During previous T700-GE-700 engine evaluations the same characteristics have been noted. A discussion of this procedure should be included in the UH-60A handbook and should be taught and demonstrated during transition and refresher training.

CONTINGENCY POWER

16. The contingency power characteristics of the T700-GE-701A engines were evaluated at the conditions shown in table 1 with one engine power lever set at idle. Compared with the T700-GE-700 engine, the 701A engine two and one-half minute CRP provides a 10% increase to 1723 SHP at sea level standard day conditions and a 22% increase to 1443 SHP at 4000 ft 95°F day conditions. A time history of an increase to CPR is presented in figure 18, appendix E. For this test, the CPR had to be pilot limited at 917°C TGT due to adjustments made to the 401 ECU used on the test engine. The 917°C limit was easy to exceed and had to be closely monitored by the pilot. While operating at CPR, engine response was the same as when operating at normal and intermediate power settings. Only stable responses were noted. The additional power available for emergency single engine operations is enhancing to the safety and survivability of the crew and aircraft and should be incorporated in future designs.

MISCELLANEOUS

17. A popping sound subsequently determined to be "oil canning" at approximate fuselage station 262 on the right side of the fuselage was heard when collective was increased to approximately 80% torque or greater. According to Sikorsky support personnel, the fuselage skin in that area had been reinforced for the heavy weight tests, then the reinforcing structure removed upon completion of these tests. This oil-canning possibly represents a weak area of the fuselage and should be monitored for structural implications.

CONCLUSIONS

GENERAL

18. Based on the PAE of the T700-GE-701A engines installed in the UH-60A helicopter the following conclusions were reached:

a. The operation of this engine installation was satisfactory except for the shortcomings noted below.

b. The CPR available for emergency single engine operation enhances the safety and survivability of the crew and aircraft.

c. Two enhancing characteristics and two shortcomings were identified.

ENHANCING CHARACTERISTICS

19. The following enhancing characteristics were identified:

a. The added contingency power available for emergency single engine operations (para 16)

b. The excellent torque matching engine stability and rotor speed control with one engine in ECU lockout and the power lever set for level flight at 80 KIAS (para 15)

SHORTCOMINGS

20. Two shortcomings were identified:

a. The slow engine acceleration during collective pulls from approximately zero torque to 50% and greater torque and during aggressive maneuvers such as a quick stop from V_H (paras 7 and 11)

b. The rotor droop to less than 95% N_R and resulting aircraft response during collective pulls from approximately zero torque to 50% or greater and during aggressive maneuvers such as a quick stop from V_H (paras 7 and 11)

RECOMMENDATIONS

21. The following recommendations are made:

a. The shortcomings reported in paragraphs 7 and 11 be corrected.

b. The enhancing characteristics noted in paras 15 and 16 be incorporated in future designs.

c. A discussion of the ECU lockout procedures discussed in para 15 should be included in the UH-60A handbook and Aircrew Training Manual (ATM).

d. Monitor the oil canning for structural implications (para 17).

APPENDIX A. REFERENCES

1. Letter, AVRADCOM, DRDAV-DI, subject: Preliminary Airworthiness Evaluation of the UH-60A Helicopter with T700-GE-701A Engines Installed. (Test Request)

2. Prime Item Development Specification, DARCOM CP-2222-S1000F, *Redline Markup for T700-GE-701A Engine Qualification Effort* 7 June 1983.

3. Model Specification, *Red Line Mark-up for T700-GE-701A Engine*, 31 May 1983.

4. Technical Manual, TM55-1520-237-10, *Operator's Manual, UH-60A Helicopter*, 21 May 1979, with change 19 dated 14 February 1983.

5. Letter, AVRADCOM, DRDAV-D, 23 June 1983, subject: Airworthiness Release for the conduct of a Preliminary Airworthiness Evaluation of the UH-60A Helicopter with the T700-GE-701A Engines Installed, Project No. 83-17.

6. Letter, USAAEFA, DAVTE-TB, 22 June 1983, subject: Test Plan Preliminary Airworthiness Evaluation of the UH-60A Helicopter with the T700-GE-701A Engines Installed, USAAEFA Project No. 83-17.

7. Paper, Anderson, William A., "Suggested Requirements for Military Helicopter Gas Turbine Engine Operating Charcteristics", published in Journal of the American Helicopter Society, Vol 12, No. 2, April 1967.

8. Army Material Command Pamphlet, AMCP No. 706-203, *Engineering Design Handbook, Helicopter Engineering Part 3 Qualification Assurance* April 1972.

APPENDIX B. ENGINE DESCRIPTION

1. The T700-GE-701A engine is a front drive, turboshaft engine featuring a single-spool gas generator section consisting of a five-stage axial, single-stage centrifugal flow compressor, a through flow annular combustion chamber, a two-stage axial flow gas generator turbine, and a free or independent two-stage axial flow power turbine. The power turbine shaft, which has a rated speed of 20,900 revolutions per minute (RPM), is co-axial and extends to the front end of the engine. The engine also incorporates modular construction throughout, an integral inlet particle separator, a top-mounted accessory package, an engine-driven fuel boost pump, a selfcontained lubrication system, condition monitoring-diagnostics provisions, a hydromechanical gas generator control system, and an electrical power control system providing power turbine speed control, dual engine load sharing, and redundant power turbine overspeed protection.

2. The T700-GE-701A engine has a contingency power (2.5 min.) rating (CPR) for use under one-engine inoperative conditions. Contingency power available for pilot use was manually selectable on the test aircraft. The production installation will automatically provide contingency power under single engine operation when a failed engine torque goes below 50%. The T700-GE-701A engine also has a 10 minute limit rating in addition to the 30 minute limit and the 2.5 minute limit.

3. The T700-GE-701A engine core has longer first stage compressor blades and increased cooling air flow to the turbine buckets, resulting in the turbine buckets seeing the same temperature as the T700-GE-700 engine. The proposed 701A standard engine instrumentation eliminates the oil temperature indicating system and incorporate a ΔP oil pressure indicating system referenced to the internal B-sump pressure. The T700-GE-700 engine has overspeed protection at 106% power turbine speed (N_P) which cycles the fuel flow between minimum and maximum. The T700-GE-701A engine has overspeed protection which cuts off all fuel flow at 120% N_P. The -700 engine has a sea level standard day 30 minute intermediate power rating of 1561 shaft horsepower (SHP); the 701A engine has a sea level standard day 30 minute IRP limit of 1694 SHP and a 2.5 minute CPR of 1723 SHP. The -700 engine has a hot day (4000 feet, 95°F) 30 minute rating of 1181 SHP; the 701A engine has a hot day 30 minute limit of 1295 SHP, a 10 minute limit of 1350 SHP and a 2.5 minute CPR of 1443 SHP. Engine turbine gas temperature (TGT) limits for the -700 engine are 775°C continuous, 850°C for 30 minutes, and 886°C for 12 seconds. TGT limits for the 701A engine are 801°C maximum continuous, 867°C for 30 minutes, 872 $\pm$5° for 10 minutes (electrical control unit (ECU) limited) and $\mp$917°C for 2.5 minutes CPR (pilot limited on test aircaft, ECU limited on production aircraft).

APPENDIX C. INSTRUMENTATION

GENERAL

1. The test instrumentation was installed, calibrated and maintained by Sikorsky Aircraft Division Personnel. A test boom, with a swiveling pitot-static tube and angle-of-attack and sideslip vanes, was installed on the nose of the aircraft. Data was obtained from calibrated instrumentation and displayed or recorded as indicated below.

Pilot Panel

- Airspeed (boom)
- Altitude (boom)
- Altitude (radar)
- Rate of climb (boom)
- Rotor speed (sensitive)
- Engine torque **
- Turbine gas temperature ($T_{4.5}$)**
- Power turbine speed (N_p)**
- Gas generator speed (N_g)**
- Control position
  - Longitudinal
  - Lateral
  - Directional
  - Collective
- Horizontal stabilator position
- Normal acceleration at cg
- Angle of sideslip

Copilot Panel

- Airspeed (ship)
- Altitude (ship)
- Fuel remaining
- Free air temperature
- Time code display
- Run number

2. Data parameter recorded on board the aircraft include the following:

Digital (PCM) Data Parameters

- Power turbine speed (N_p)**
- Gas generator speed (N_g)**

**Both engines

Turbine gas temperature ($T_{4.5}$)**
Main rotor speed
Fuel used **
Engine torque**
Power available spindle position**
Load demand spindle position**
Fuel flow**
Main rotor shaft extension torque
Tail rotor torque
Tail rotor impressed pitch
Control position
  Longitudinal
  Lateral
  Pedal
  Collective
Horizontal stabilator position
Sideslip angle
Angle-of-attack
Aircraft attitude
  Pitch
  Roll
  Yaw
Angular Velocity
  Pitch
  Roll
  Yaw
Angular acceleration
  Pitch
  Roll
  Yaw
Normal load factor @ cg
Airspeed (boom)
Airspeed (ship)
Altitude (boom)
Rate of climb (boom)

**Both engines

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. The T700-GE-701A engine handling characteristics were evaluated using the basic methods described in references 7 and 8, appendix A. All test data were recorded using test instrumentation and recorded on magnetic tape installed in the aircraft. The data are presented as time histories of pertinent engine parameters.

ENGINE ACCELERATION

2. The T700-GE-701A engine acceleration characteristics were evaluated using dual and single engine collective pulls to Intermediate rated power (IRP) from predetermined power settings. These power settings varied incrementally from 80 percent torque down to zero torque (autorotation). The target rates of application were for a ramp input varying from five to one seconds. The aircraft was stabilized at the test altitude and airspeed. The data recorder was turned on, the ramp input completed, and the dynamic response was recorded. On those points where the rotor drooped to less than 95 percent, the collective was reduced to effect recovery when the low rotor speed visual and audio warning were observed.

ENGINE DECELERATION

3. The T700-GE-701A engine deceleration characteristics were evaluated using dual and single engine collective ramp reduction to full down collective. The aircraft was stabilized, the data recorder activated, and the input completed as described in paragraph 2.

PULL-UP AND PUSH-OVER

4. The T700-GE-701A engine response during pull-up and push-over maneuvers was evaluated by stabilizing the aircraft in level flight, turning the data recorder on and applying an aft cyclic input to decelerate the aircraft followed by a forward cyclic input to accelerate the aircraft to a nominal speed above the stabilized airspeed.

STATIC DROOP

5. The T700-GE-701A engine static droop characteristics were evaluated by setting the rotor speed to 100 percent on the ground

at flat pitch, then performing takeoff, IRP climb, level flight maneuvers, autorotational descent and landing while observing the static changes in rotor speed during the various flight configurations.

QUICK STOP

6. The T700-GE-701A engine response characteristics during quick stop maneuvers were evaluated by accelerating to maximum level flight airspeed, turning on the data recording system, then reducing the collective to the full down position while applying aft cyclic to maintain constant altitude. The data are presented as a time history of pertinent engine parameters.

LONGITUDINAL FLARE DECELERATION

7. The T700-GE-701A engine response characteristics during longitudinal flare decelerations were evaluated by accelerating to maximum level flight airspeed, turning on the data recording system, performing a collective fixed deceleration by applying aft cyclic, and allowing airspeed and altitude to vary until the airspeed decreased to zero.

JUMP TAKEOFF

8. The T700-GE-701A engine response characteristics during jump takeoffs were evaluated by applying collective until the aircraft was light on wheels, turning the data recording system on, then making a ramp collective input to the IRP setting. Varying rates of application were evaluated as a buildup to a one second ramp input to IRP.

ENGINE STABILITY

9. The T700-GE-701A engine stability characteristics were evaluated by stabilizing the aircraft in level flight, turning on the data recording system and applying collective and pedal pulses at various rates until the apparent natural frequency was determined. The controls were then pulsed at this rate for several seconds to determine if any divergent oscillation characteristics were present. The collective was returned to the initial setting (mean of the pulse input) and the damping characteristics were evaluated prior to turning off the data recorder.

ENGINE ELECTRICAL CONTROL UNIT LOCKOUT

10. The T700-GE-701A engine and rotor speed response characteristics while operating in ECU lockout were evaluated by stabilizing in level flight at 80 knots indicated airspeed (KIAS). The data recorder was turned on, one engine placed in ECU lockout and the locked out engine set at various power settings above and below the ECU controlled engine. The locked out engine was then torque matched to the other engine, the aircraft accelerated to maximum level flight airspeed, then decelerated to approach speed, hover, and landing with the collective placed at flat pitch without resetting the locked out engine power lever.

CONTINGENCY POWER

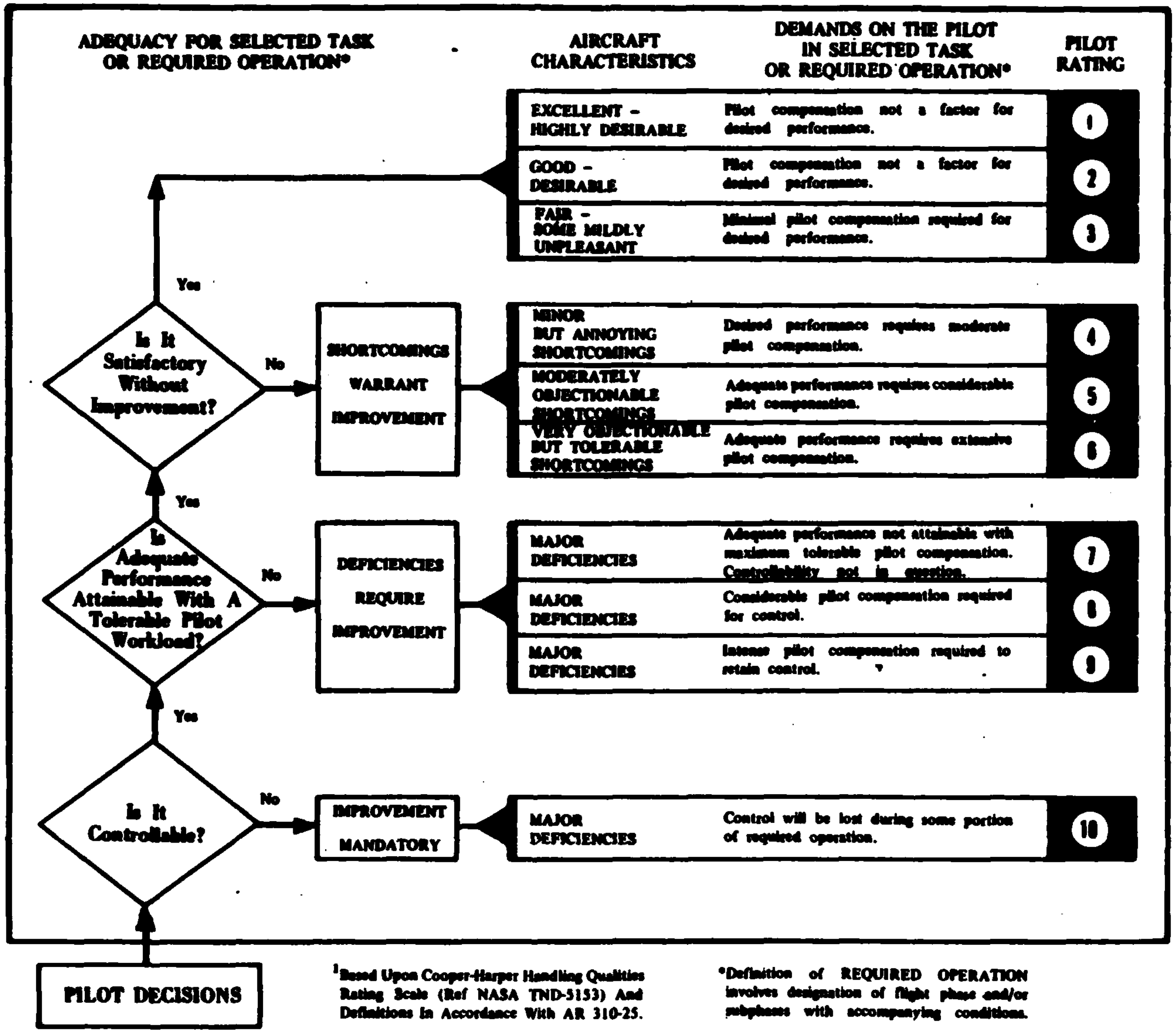
11. The T700-GE-701A contingency power characteristics were evaluated by stabilizing the aircraft in level flight, placing one engine power lever to idle, turning on the data recorder, activating the pilot controlled contingency power switch and increasing collective to contingency power limits. The limits had to be pilot monitored due to the test engine configuration (see engine description, app B).

DEFINITION

12. The following definition of a shortcoming was used during this evaluation: Shortcoming - An imperfection or malfunction occurring during the life cycle of equipment which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the useability of the material or end product.

HANDLING QUALITIES RATING SCALE

13. A Cooper-Harper Handling Qualities Rating Scale (HQRS) (fig. 1) was used to augment pilot comments relative to handling qualities.



[1]Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) And Definitions In Accordance With AR 310-25.

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

Figure 1. Handling Qualities Rating Scale

APPENDIX E. TEST DATA

FIGURE 1

DUAL ENGINE COLLECTIVE PULL

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	4000	21.0	258	PARTIAL POWER DESCENT	80

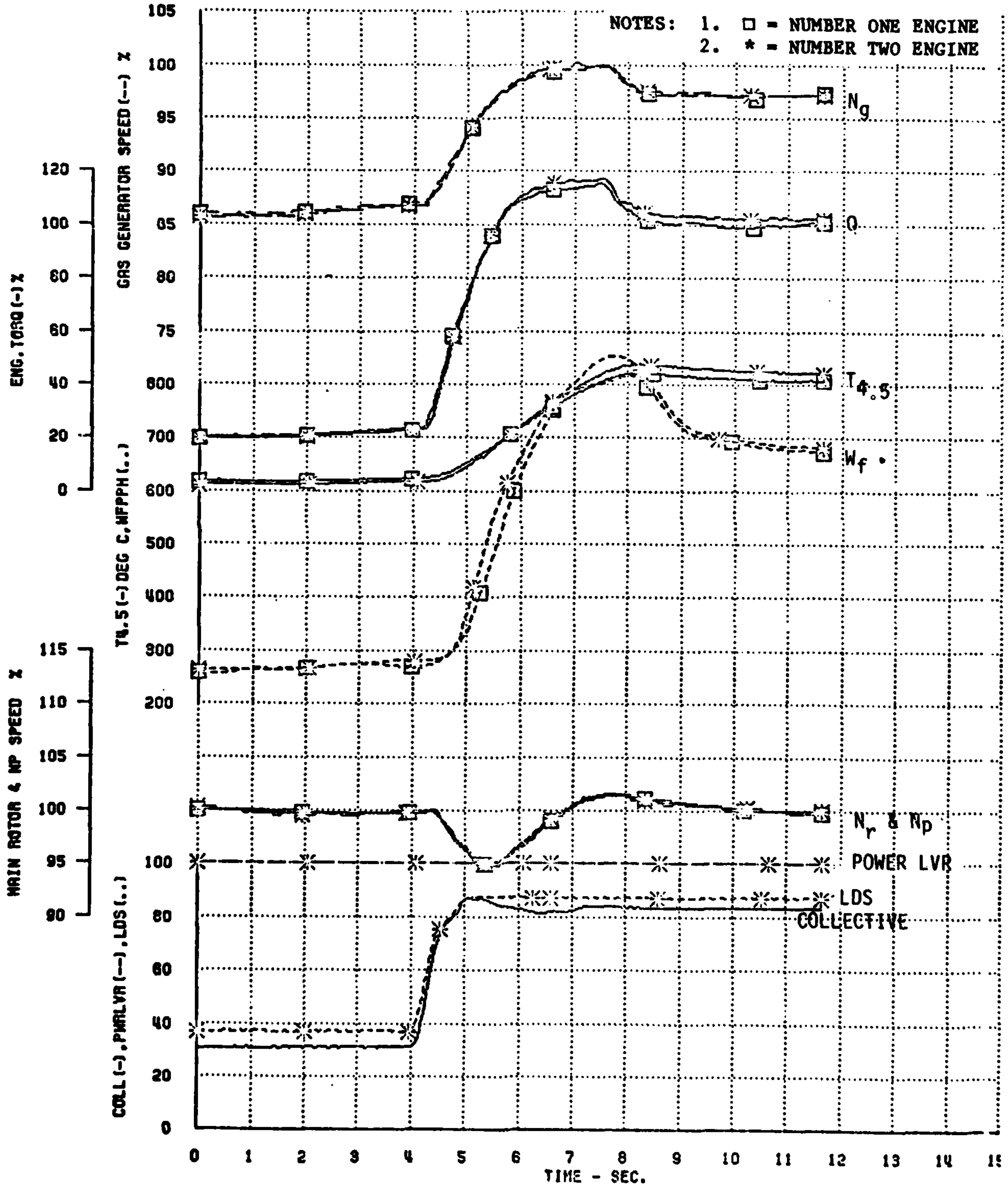


FIGURE 2

DUAL ENGINE COLLECTIVE PULL

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	4800	21.0	258	AUTOROTATION	80

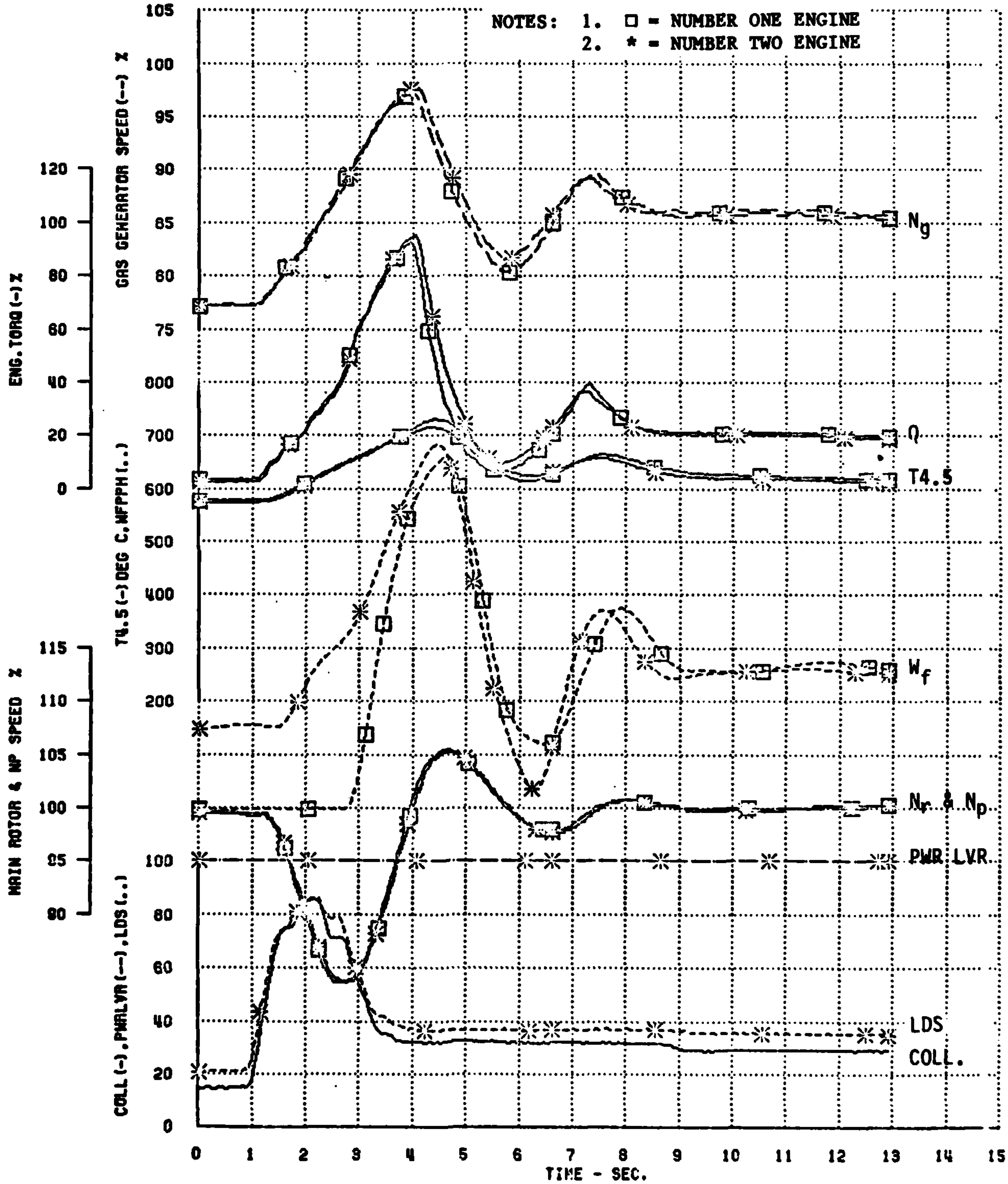


FIGURE 3

SINGLE ENGINE COLLECTIVE PULL

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	4170	21.0	258	PARTIAL POWER DESCENT	80

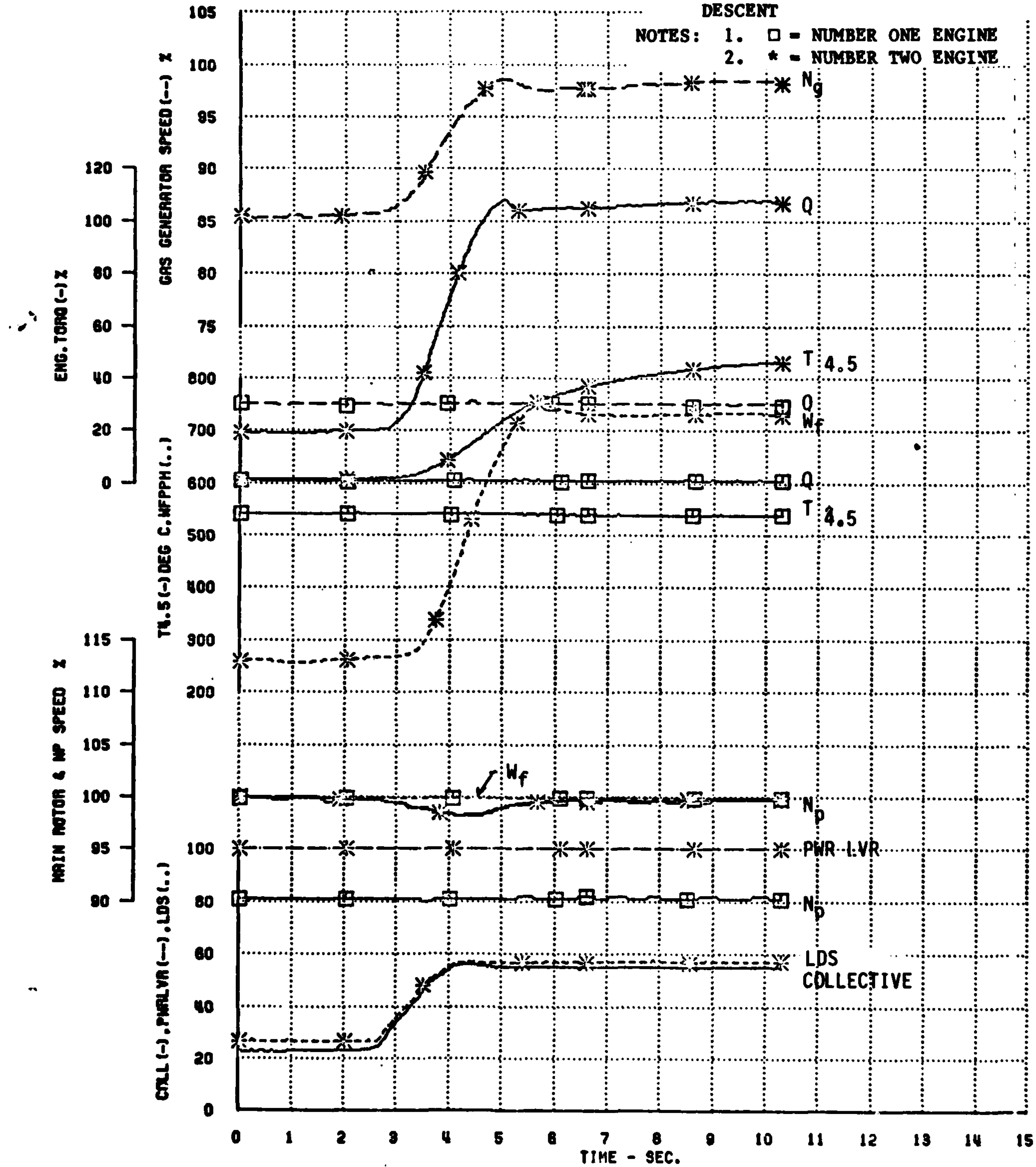


FIGURE 4

SINGLE ENGINE COLLECTIVE PULL

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	4700	21.0	258	AUTOROTATION	80

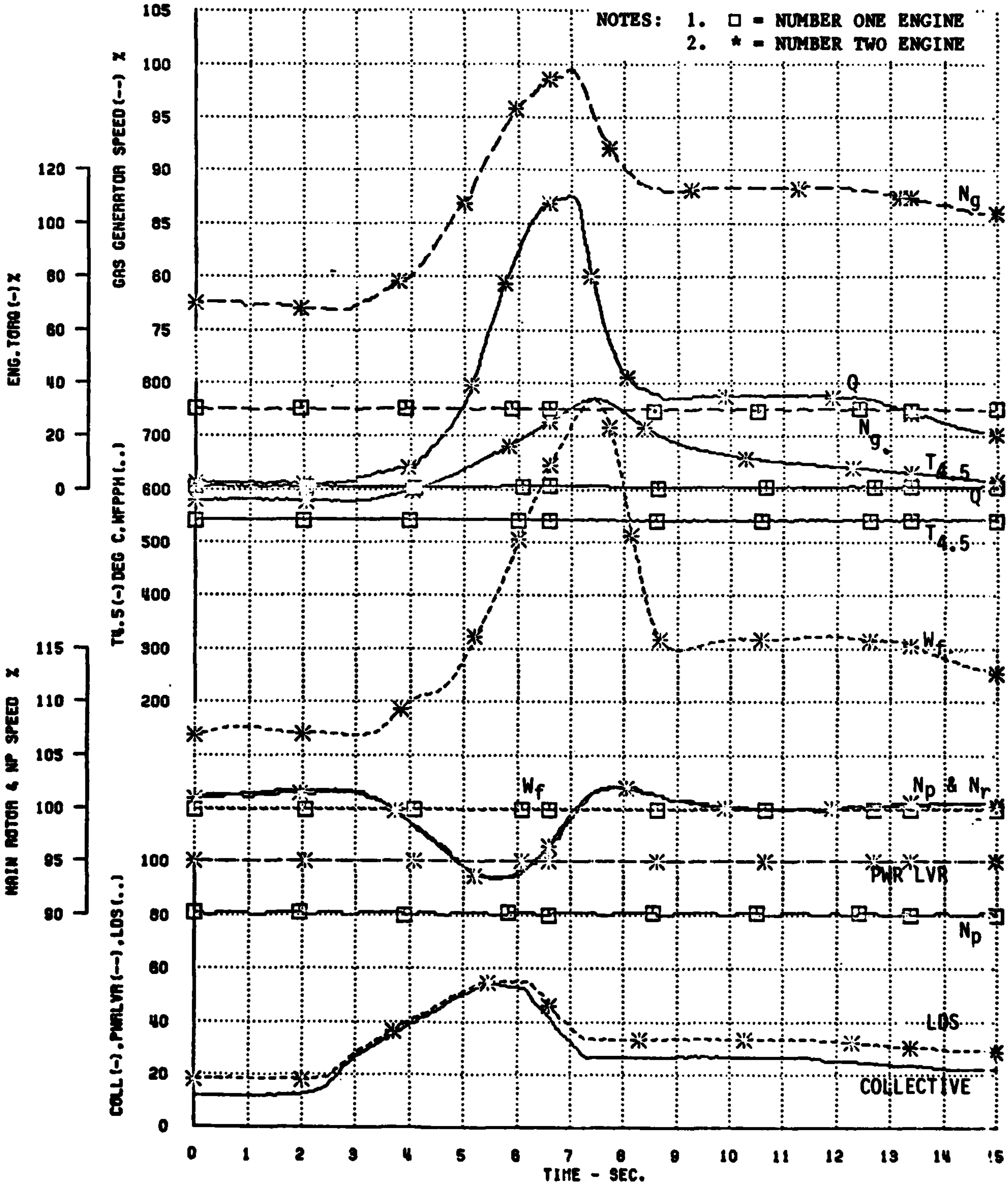


FIGURE 5

SINGLE ENGINE COLLECTIVE PULL

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
18,000	354.0 (MID)	4000	21.5	258	AUTOROTATION	80

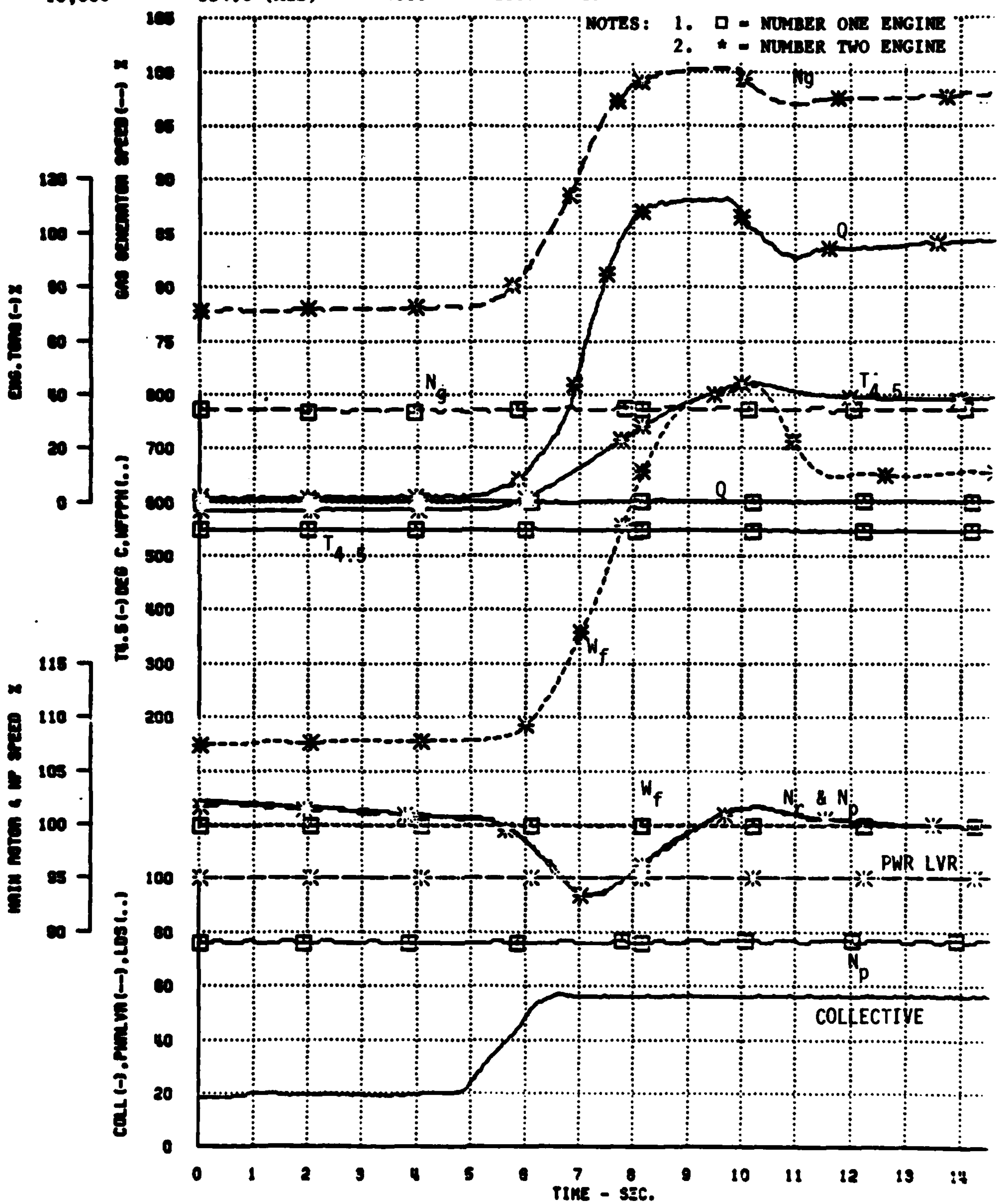


FIGURE 6

DUAL ENGINE COLLECTIVE PULL

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
18,000	354.0 (MID)	4000	21.5	258	AUTOROTATION	80

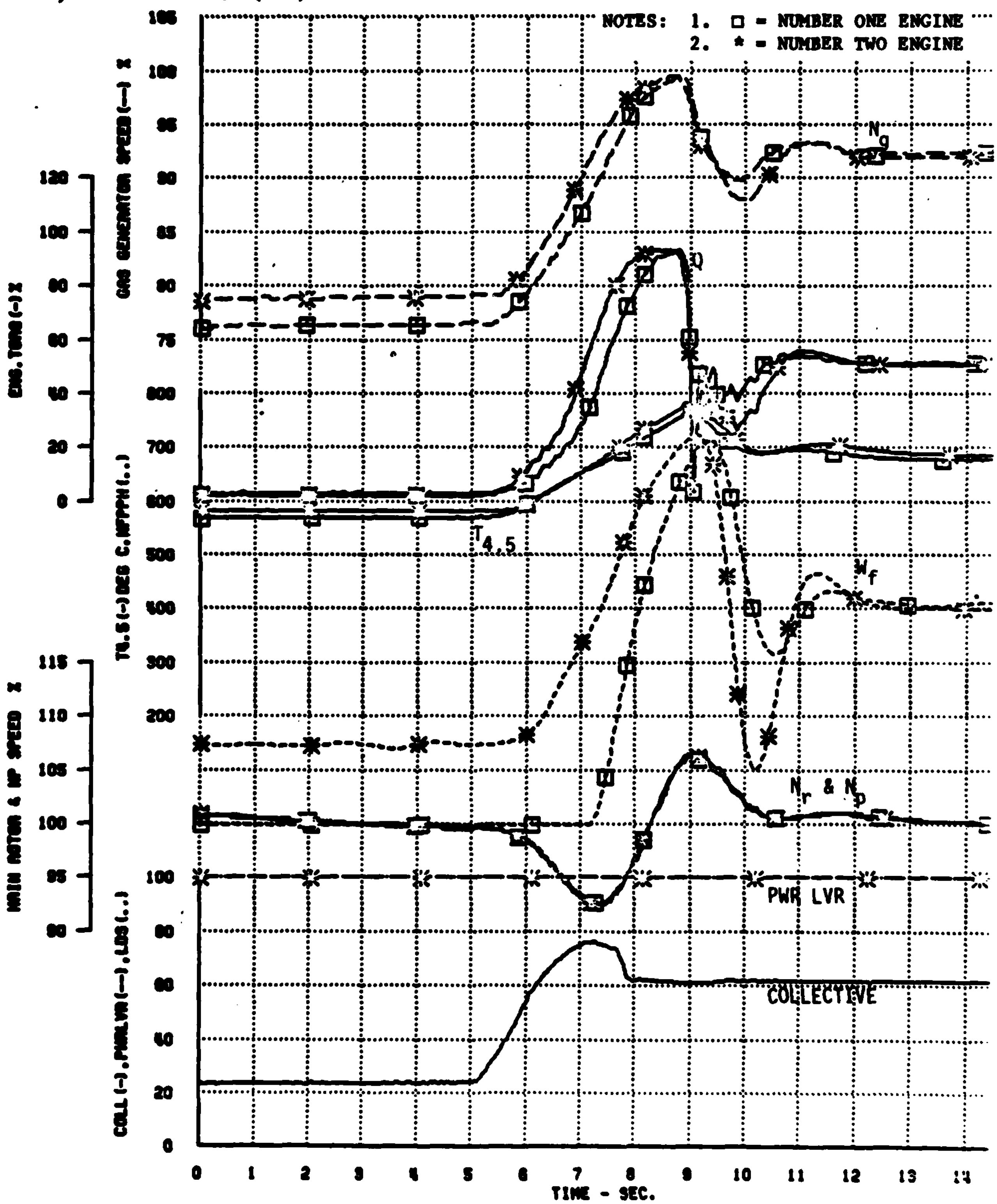


FIGURE 7

DUAL ENGINE DECELERATION

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	5400	19.5	258	MAX POWER CLIMB	80

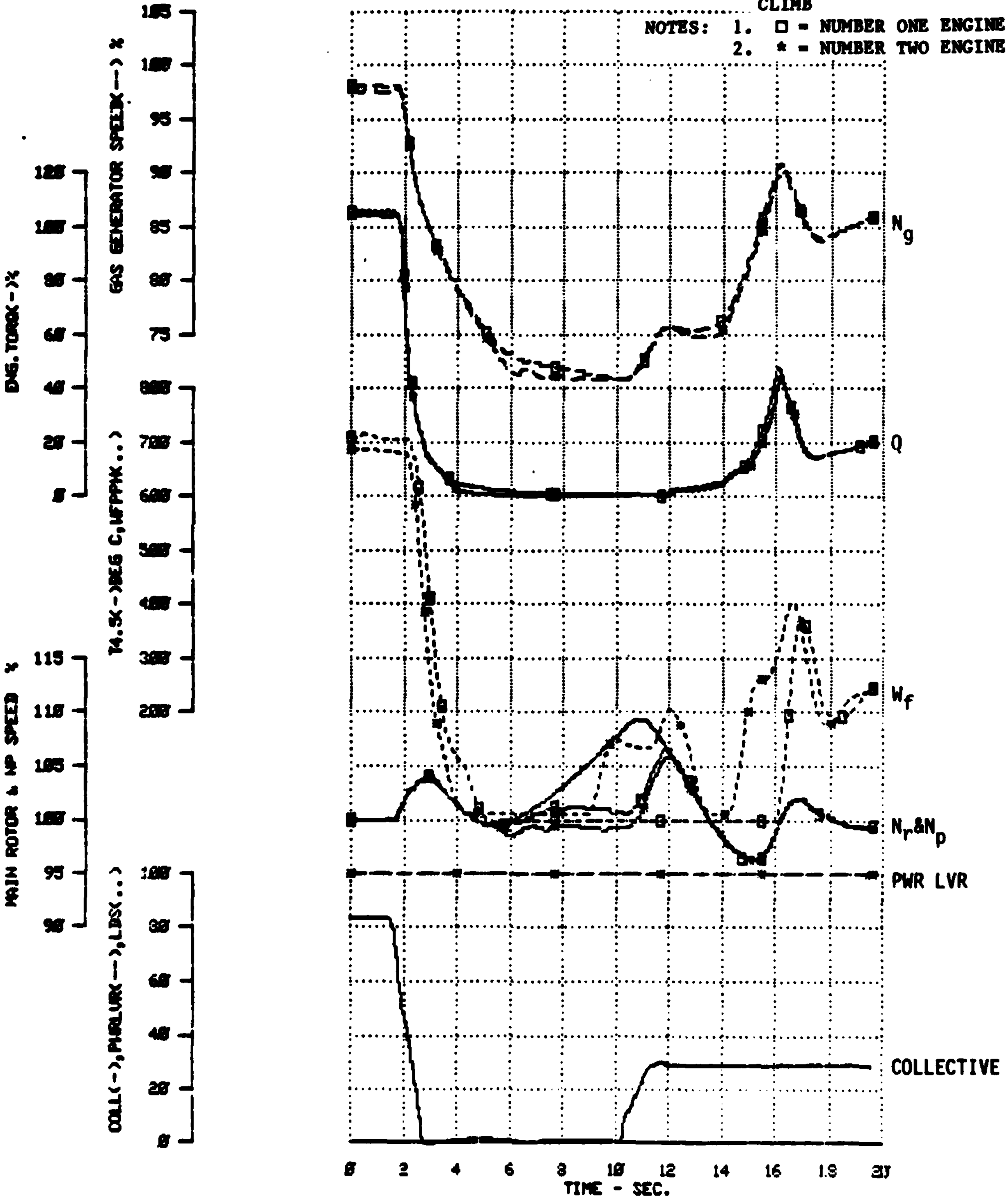


FIGURE 8

DUAL ENGINE DECELERATION

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	3700	21.5	258	SINGLE ENGINE MAX POWER LEVEL FLIGHT	80

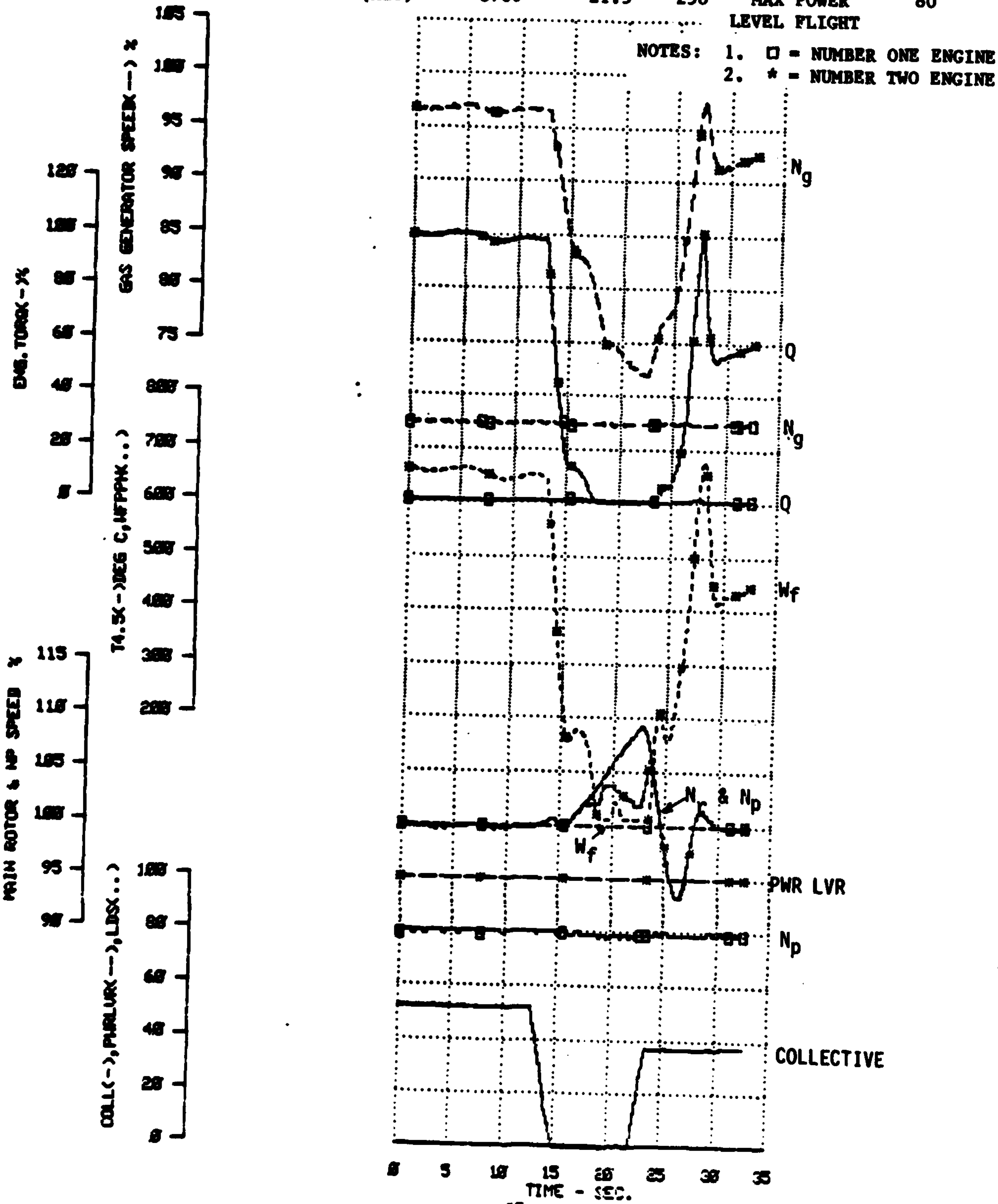


FIGURE 9

PULL-UP AND PUSH-OVER MANEUVER

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	4400	20.0	258	LEVEL FLIGHT	80

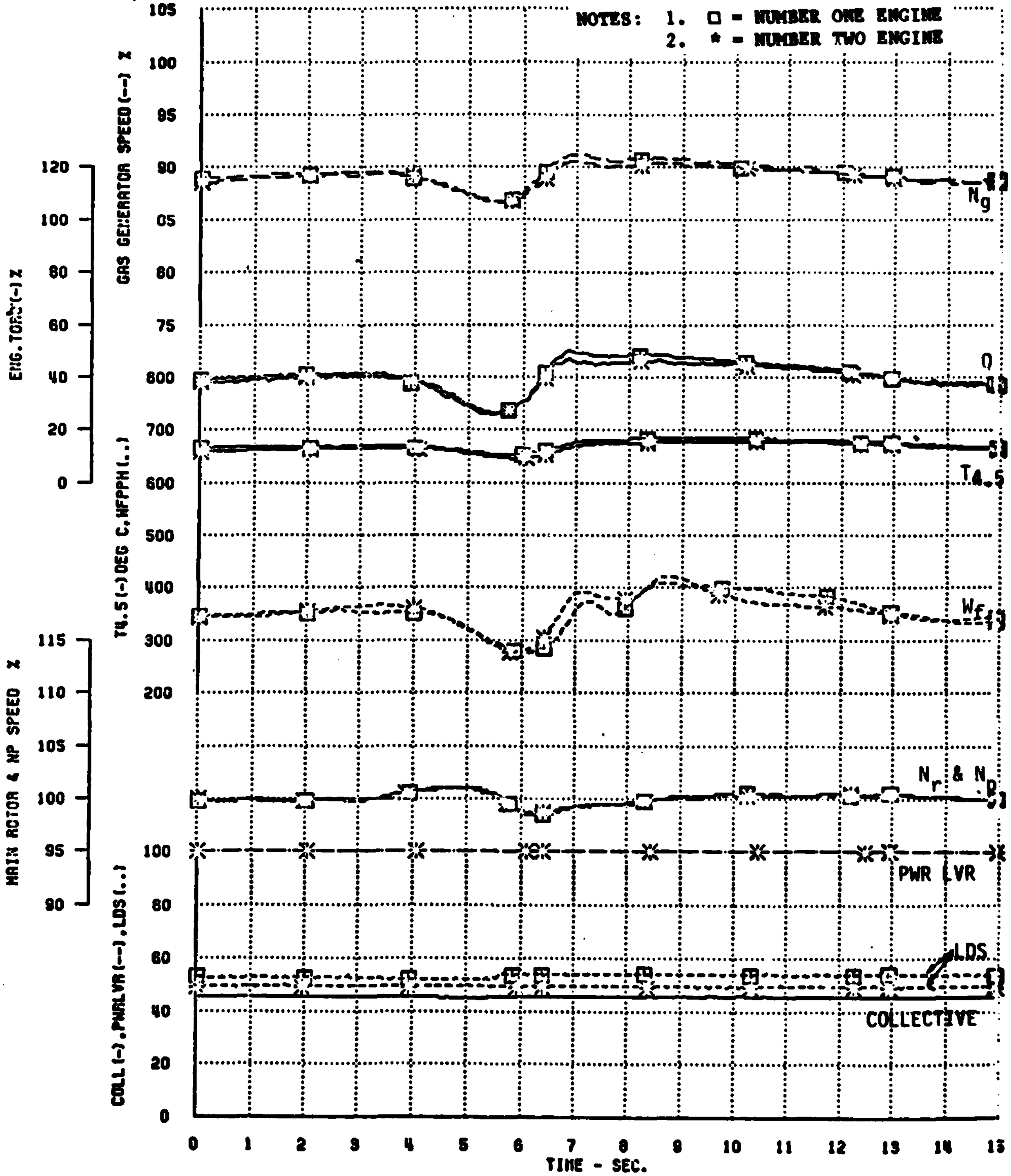


FIGURE 10

QUICK STOP MANEUVER

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	1750	28.0	258	LEVEL FLIGHT	150

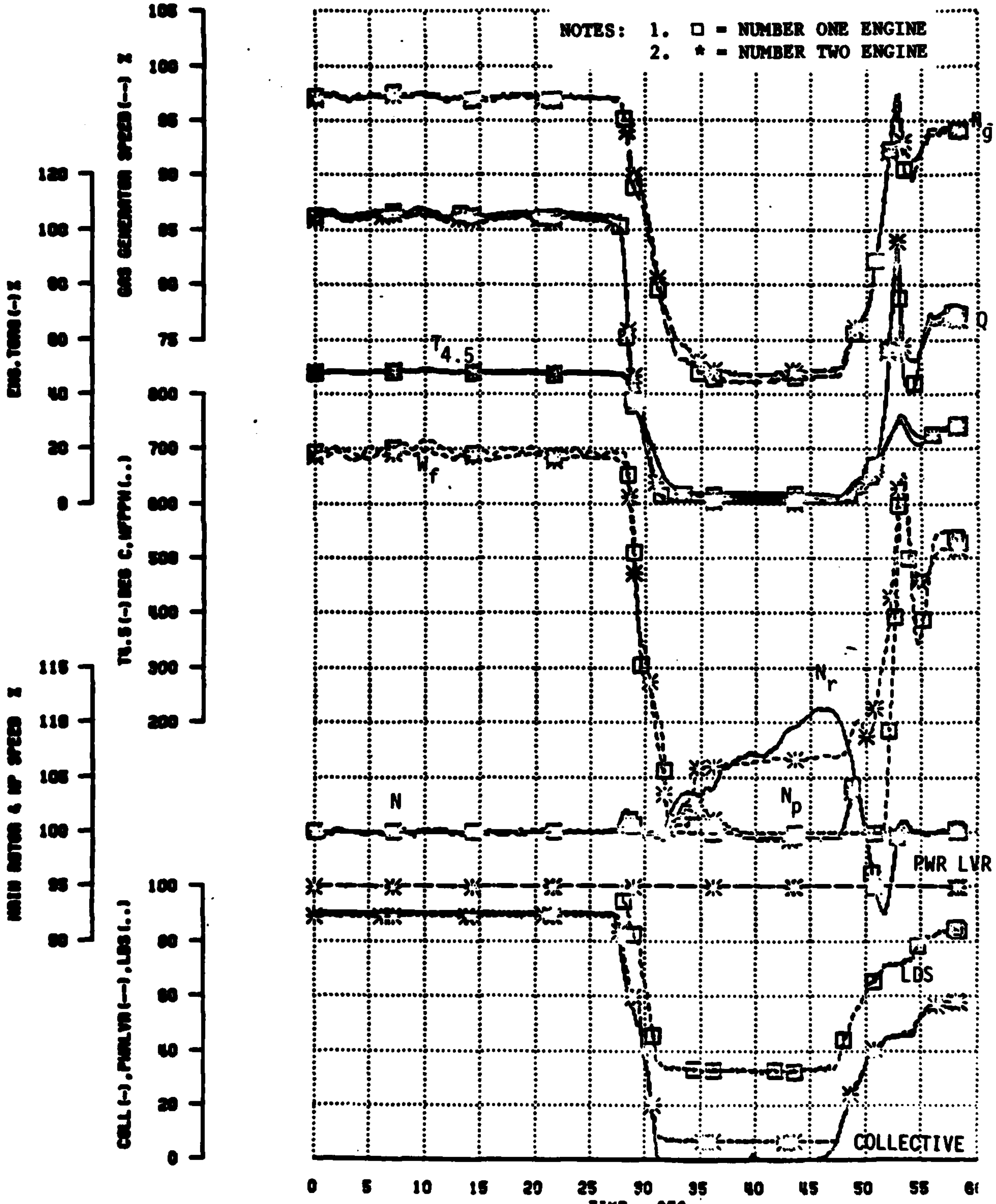


FIGURE 11

LONGITUDINAL FLARE DECELERATION MANEUVER

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	3800	21.5	258	LEVEL FLIGHT	150

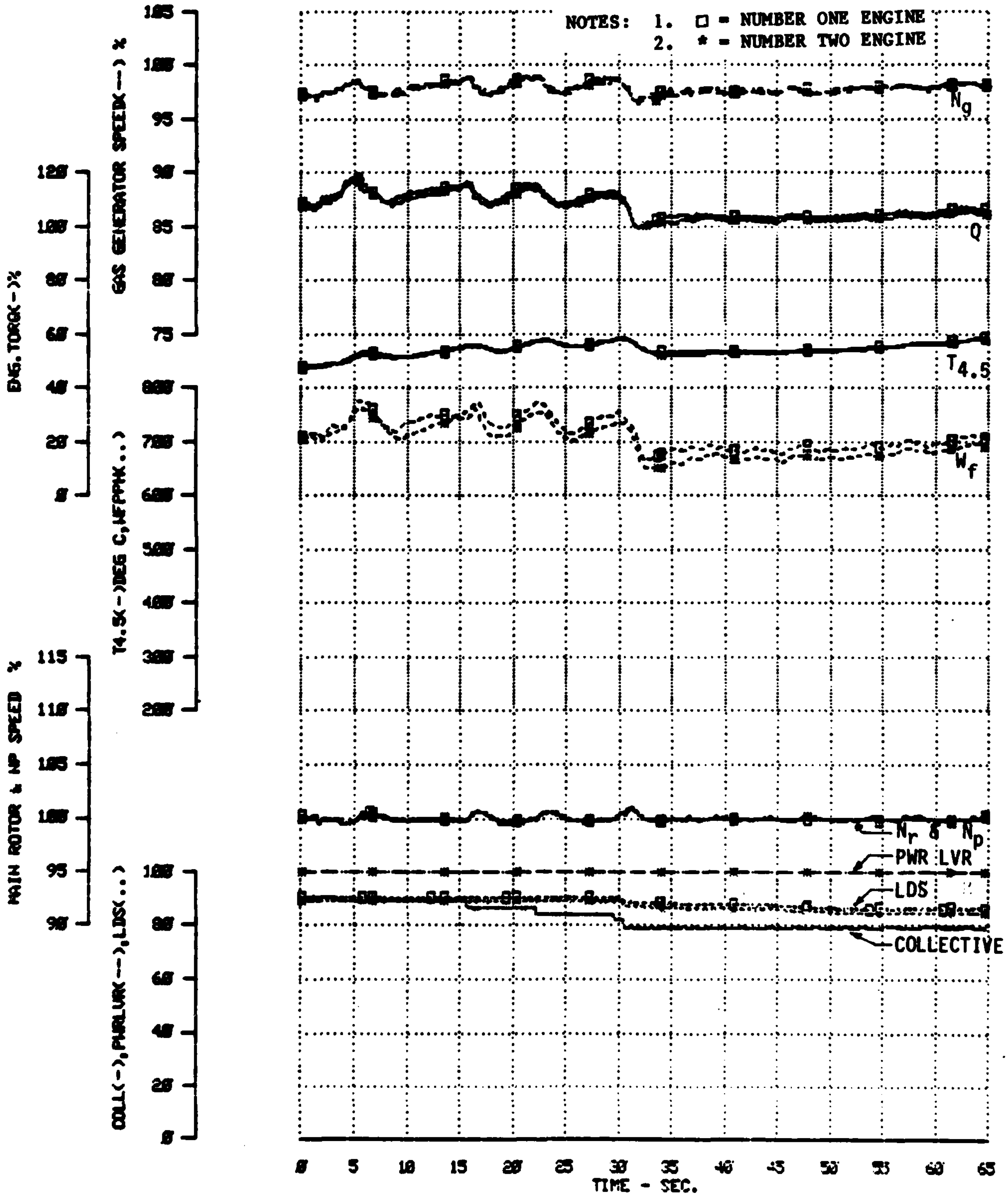


FIGURE 12

JUMP TAKEOFF

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	1700	28.5	258	LIGHT ON WHEELS	0

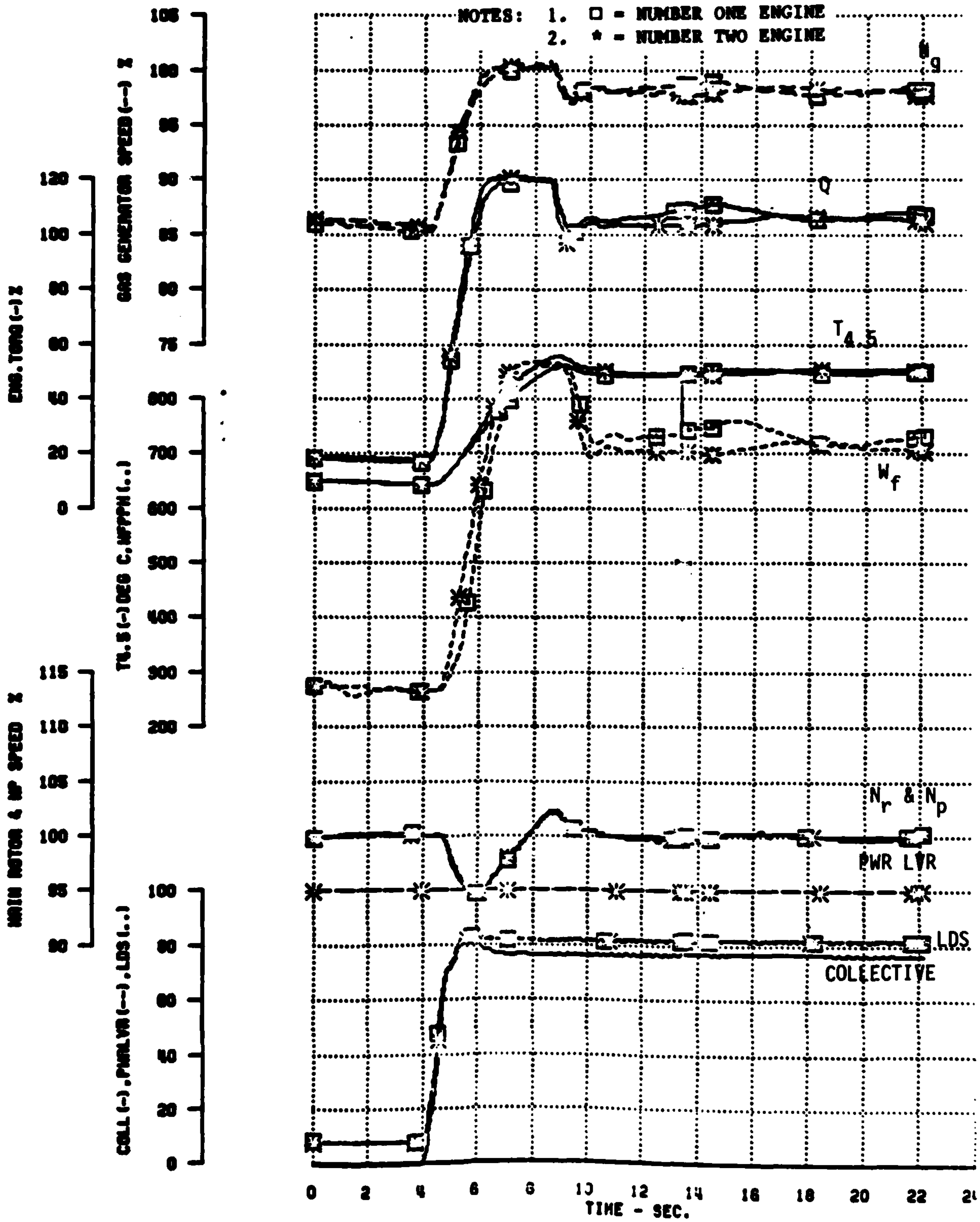


FIGURE 13

JUMP TAKEOFF

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	1700	28.5	258	LIGHT ON WHEELS	0

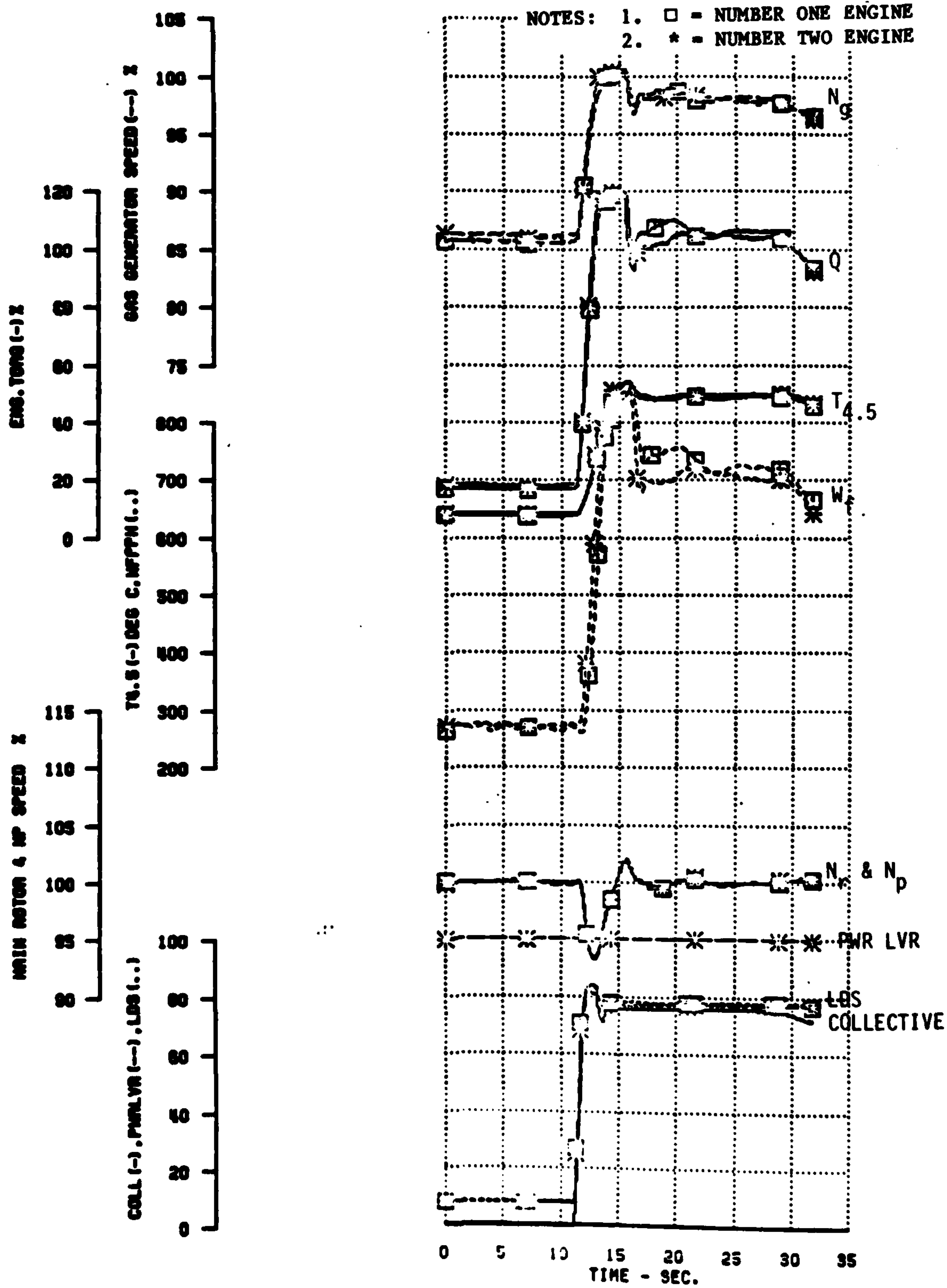


FIGURE 14

COLLECTIVE PULSES

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	5400	18.5	258	LEVEL FLIGHT	80

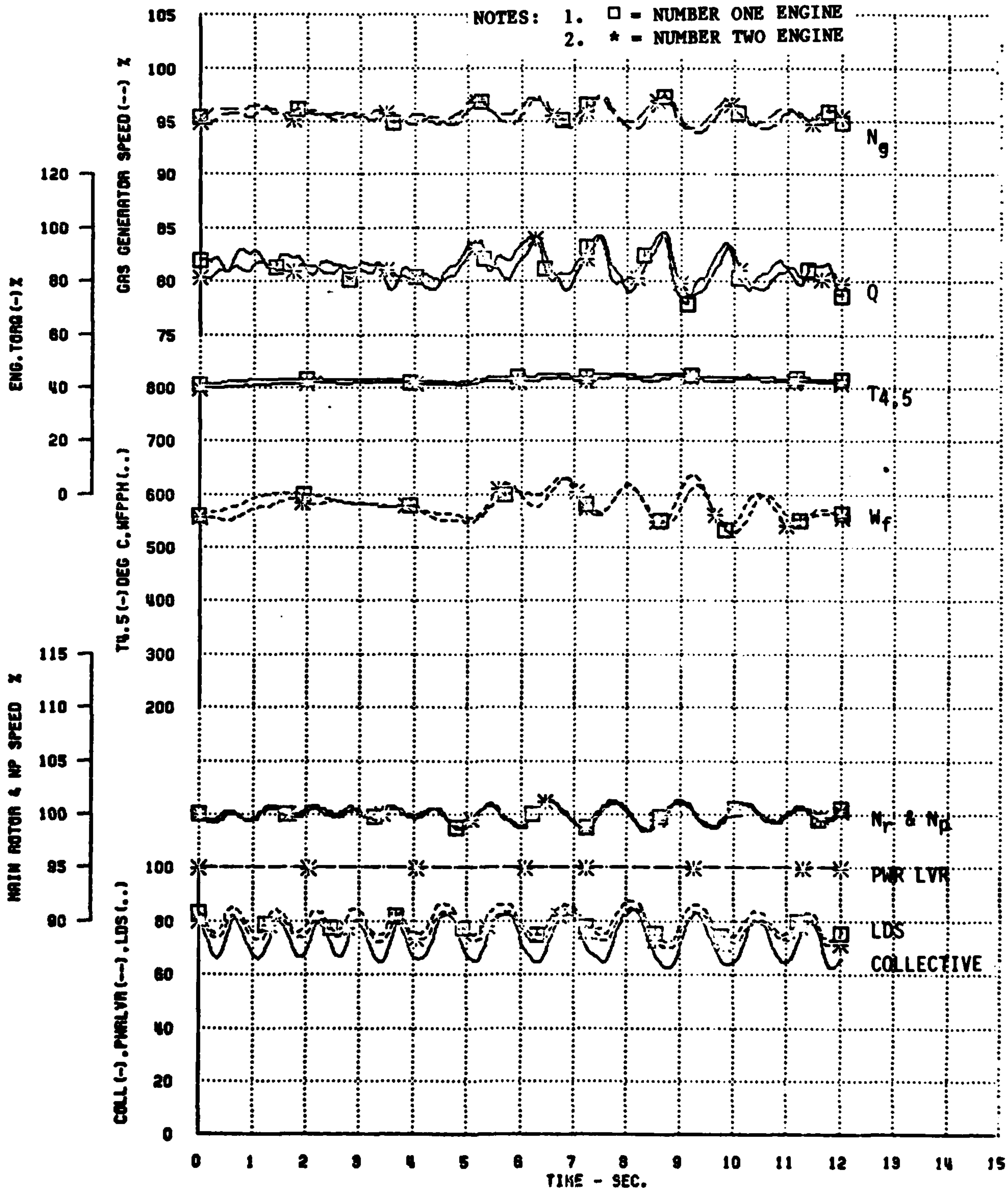


FIGURE 15

PEDAL PULSES

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	5000	19.0	258	LEVEL FLIGHT	80

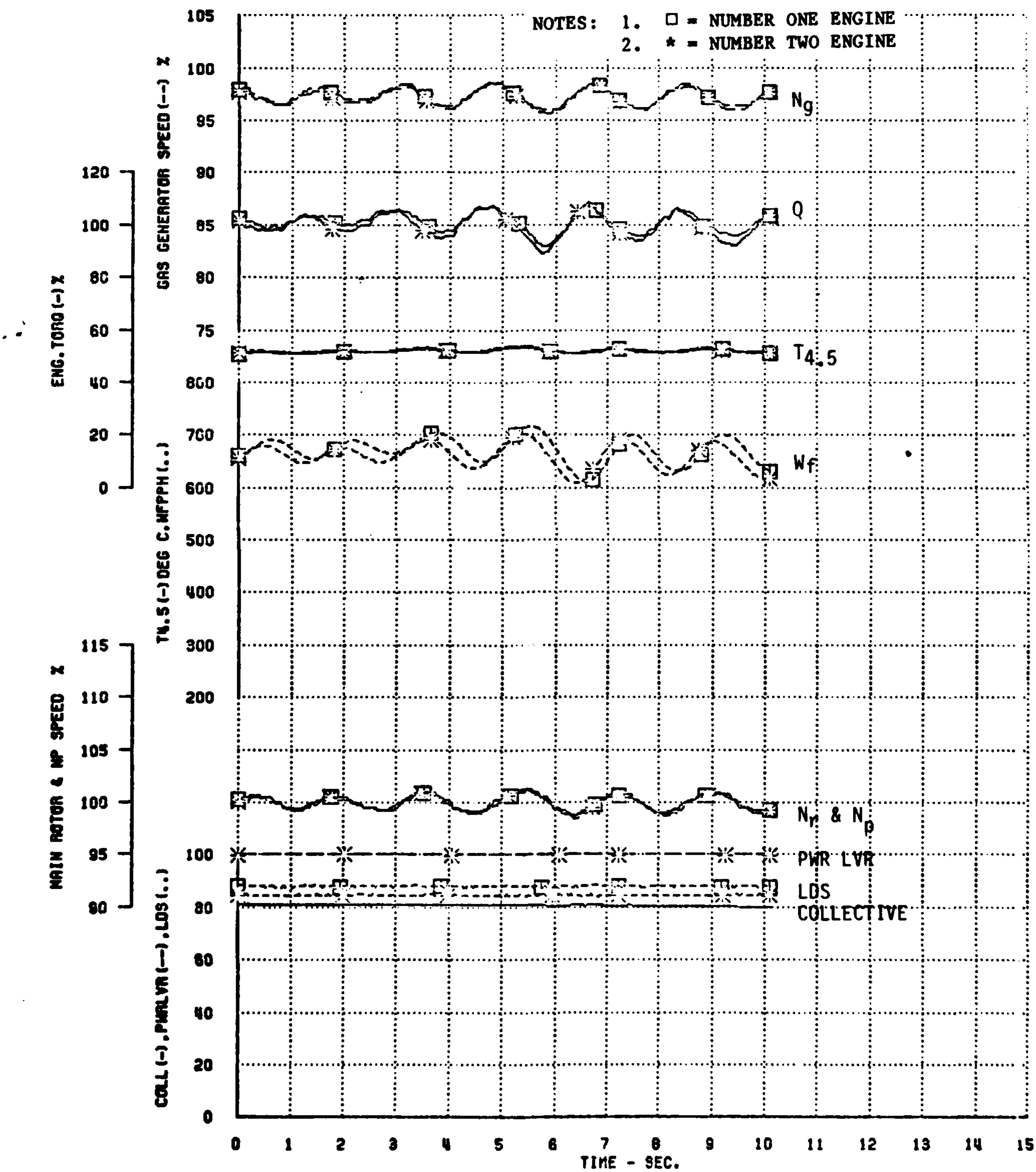


FIGURE 16

COLLECTIVE PULSES

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	4400	20.5	258	LEVEL FLIGHT	80

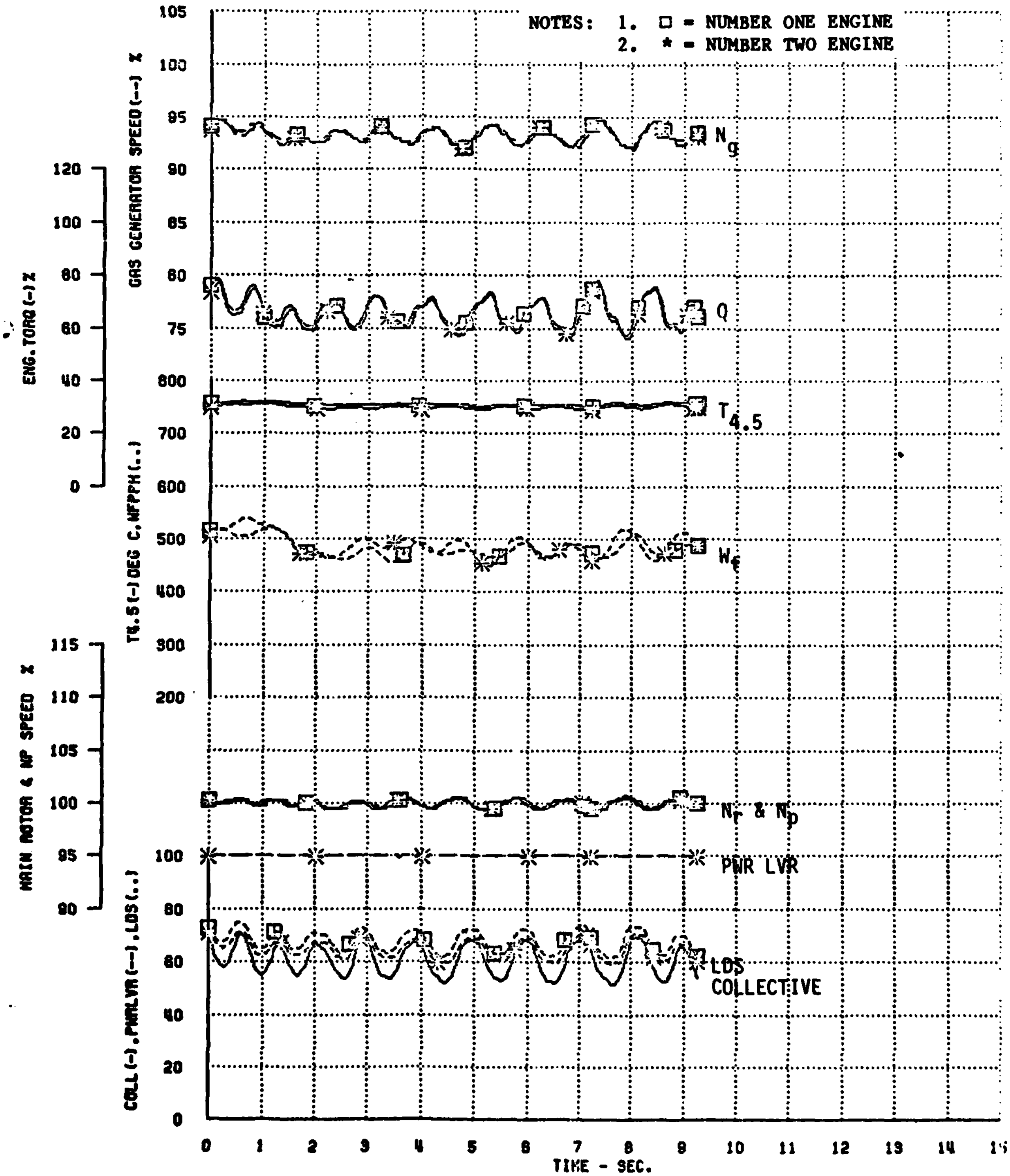


FIGURE 17

NUMBER ONE ENGINE IN ECU LOCKOUT

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	5250	18.5	258	LEVEL FLIGHT	80

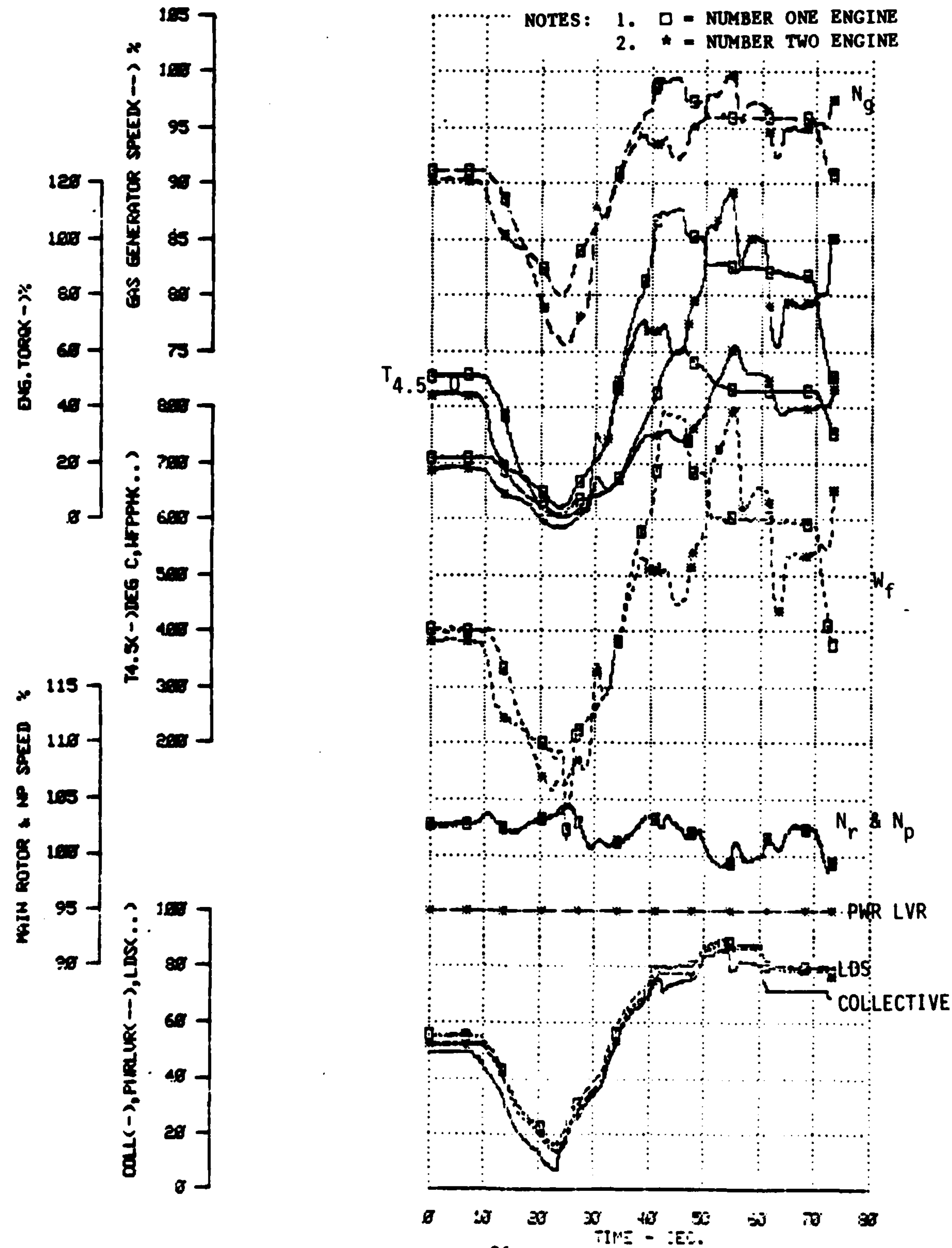
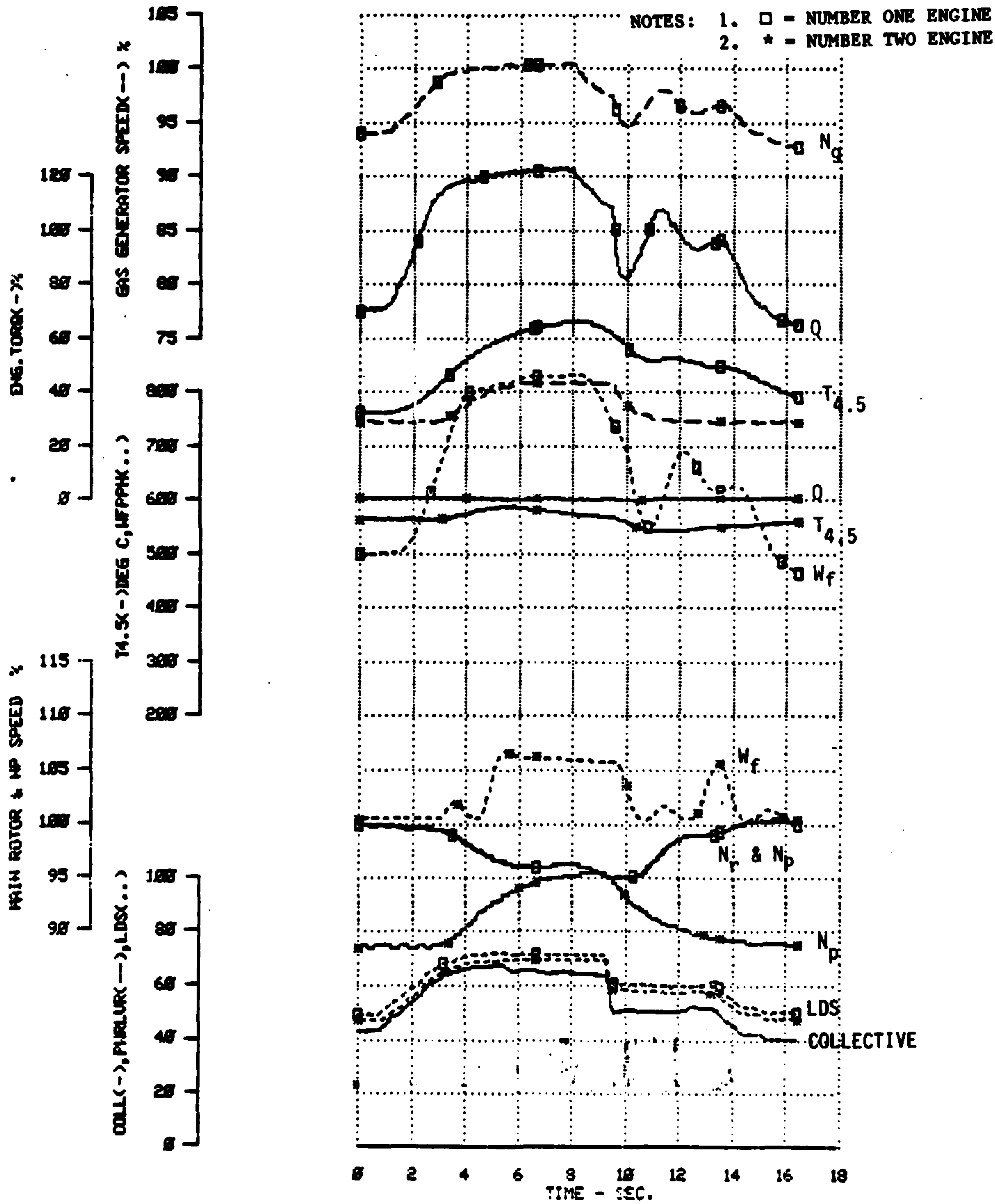


FIGURE 18

CPR OPERATION

ENGINE START GROSS WEIGHT (LB)	ENGINE START LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM INDICATED AIRSPEED (KIAS)
17,500	353.0 (MID)	4470	19.5	258	LEVEL FLIGHT	80



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